

# *Orion Abort Flight Test*

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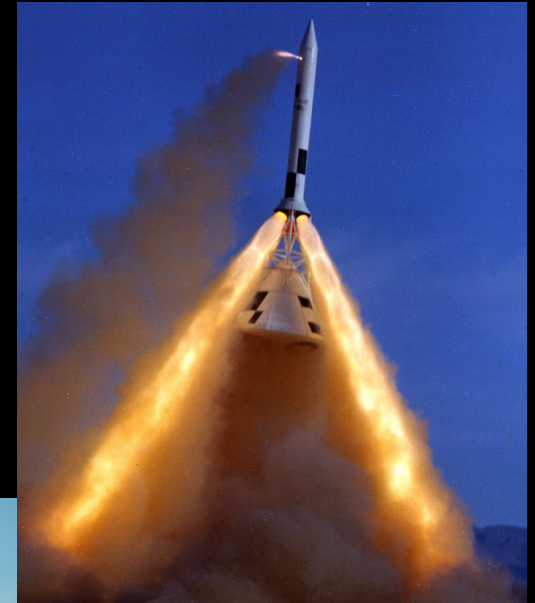
## *Recent Abort Flight Test Events*



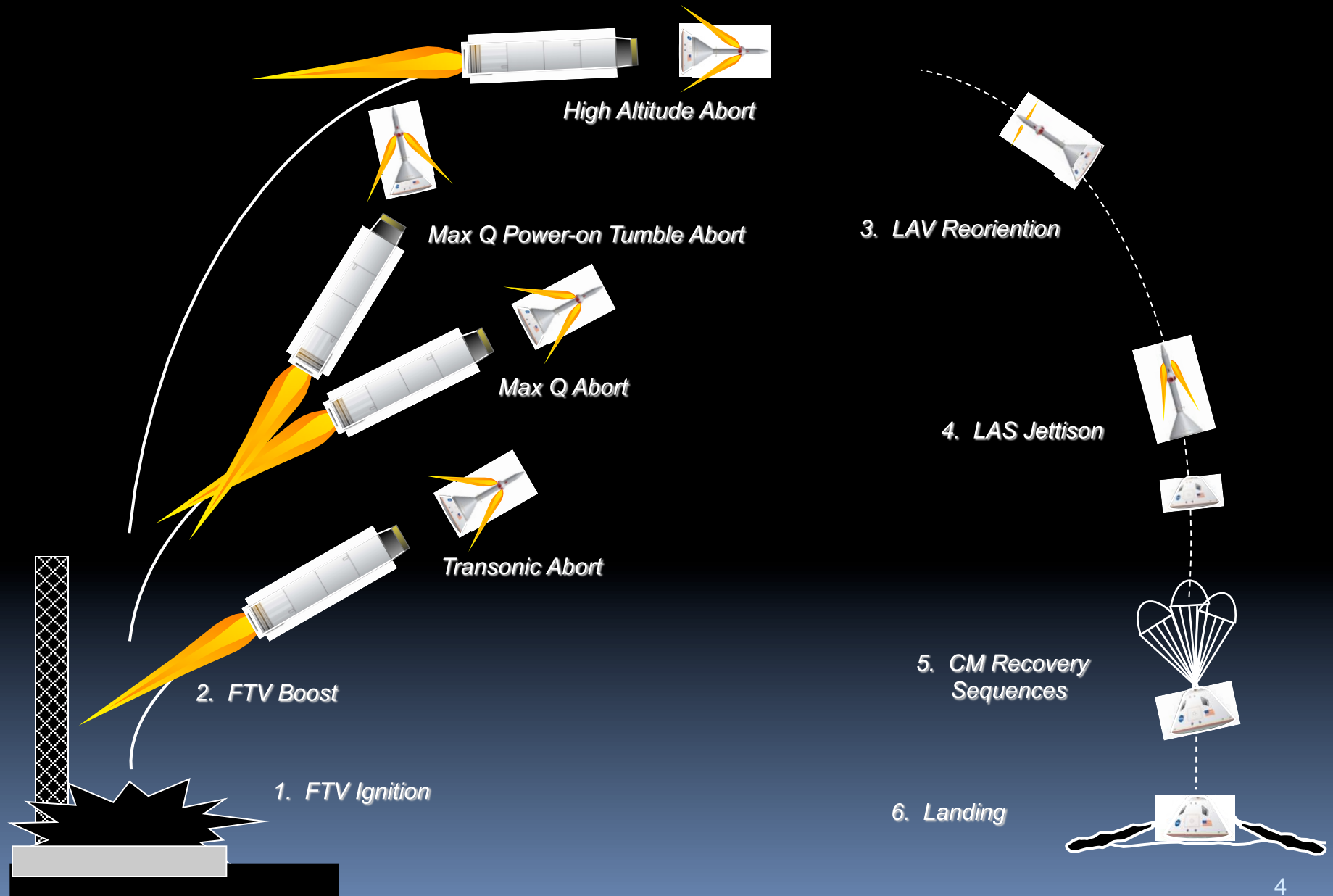
- [Pad Abort 1 flight test](#) occurred on 6 May 2010 from White Sands Missile Range in New Mexico

# Abort Flight Test

- Orion's Launch Abort System (LAS) provides an emergency escape system for the crew
- Abort Flight Test Objectives:
  - Provide adequate testing to demonstrate proper performance and function of the LAS throughout the required flight envelope
  - Validate key abort models
    - LAS performance and functionality
    - Parachute system performance and functionality
    - Separation aerodynamics
    - Separation mechanism performance
  - Pathfinder for Orion system integration and ground operations procedures

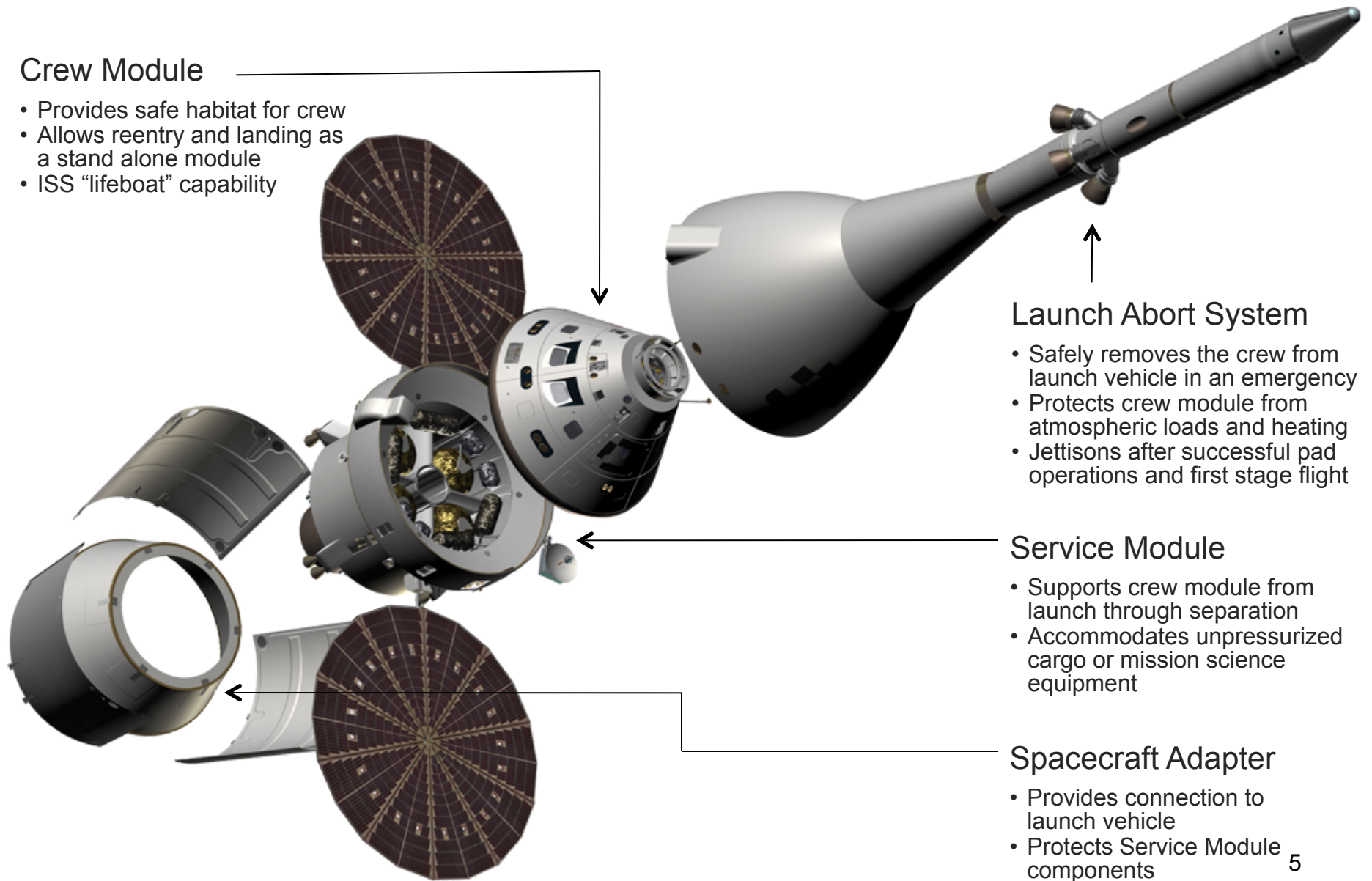


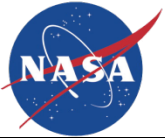
# Notional Ascent Abort Scenarios



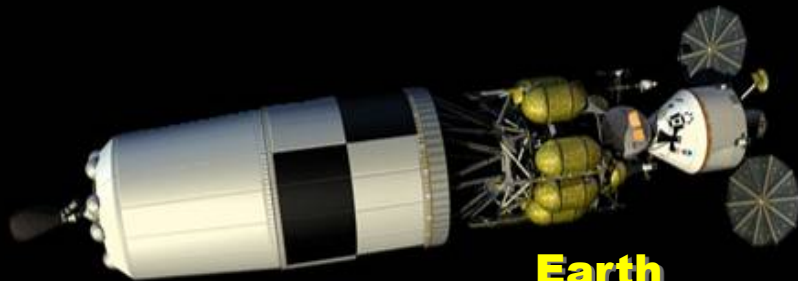


# Orion Spacecraft Overview





## Components of Program Constellation



**Earth  
Departure  
Stage**



**Orion -  
Crew  
Exploration  
Vehicle**



**Ares V -  
Heavy  
Lift  
Launch  
Vehicle**

**Ares I -  
Crew  
Launch  
Vehicle**



**Lunar  
Lander**



# Launch Abort System (LAS) and Crew Module (CM)





## *Abort Motor Test Firing*







## *Jettison Motor Firing*



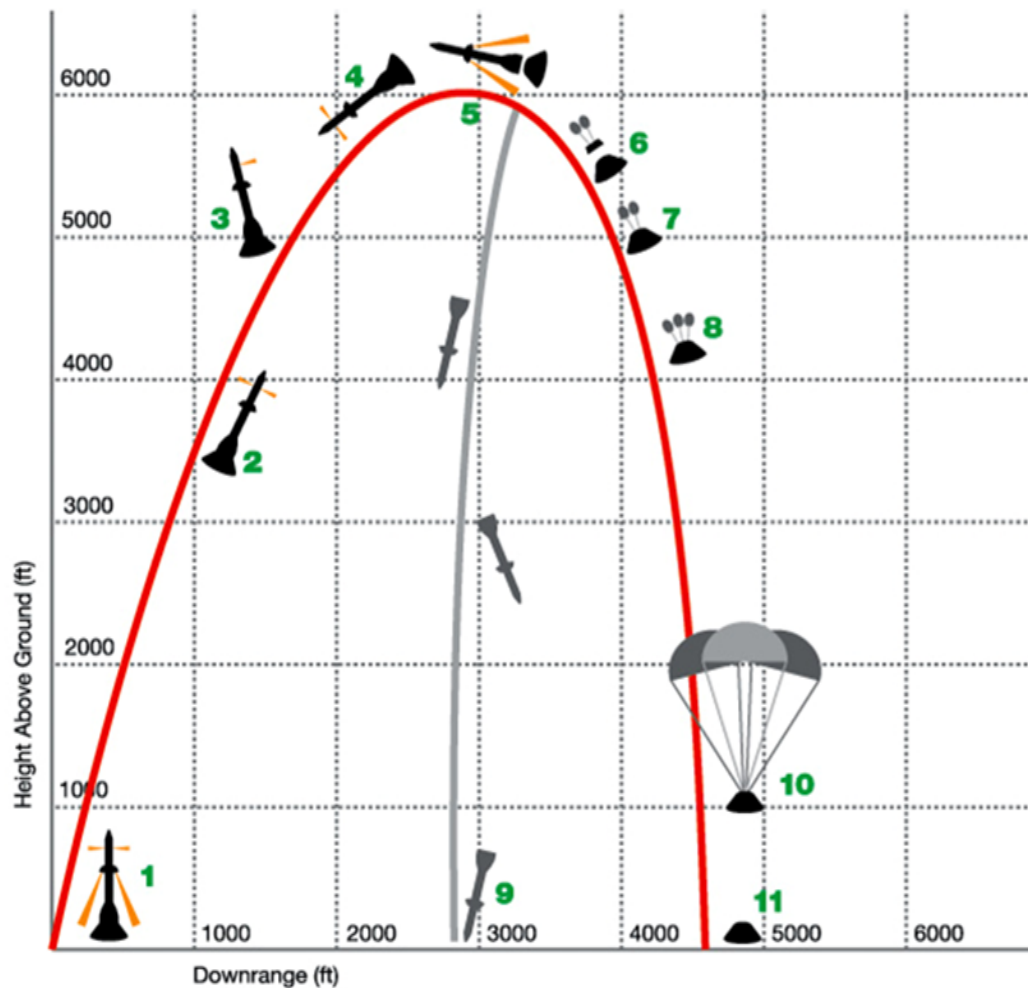


## *Attitude Control Motor Firing*





# Pad Abort 1 (PA-1) Trajectory Cartoon



## Event

1. AM/ACM ignition
2. AM burnout
3. Begin re-orientation
4. End re-orientation
5. LAS Jettison
6. FBC jettison
7. Drogue mortar fire
8. Pilot mortar fire
9. LAS touchdown
10. Reach 33 ft/sec descent rate
11. CM touchdown

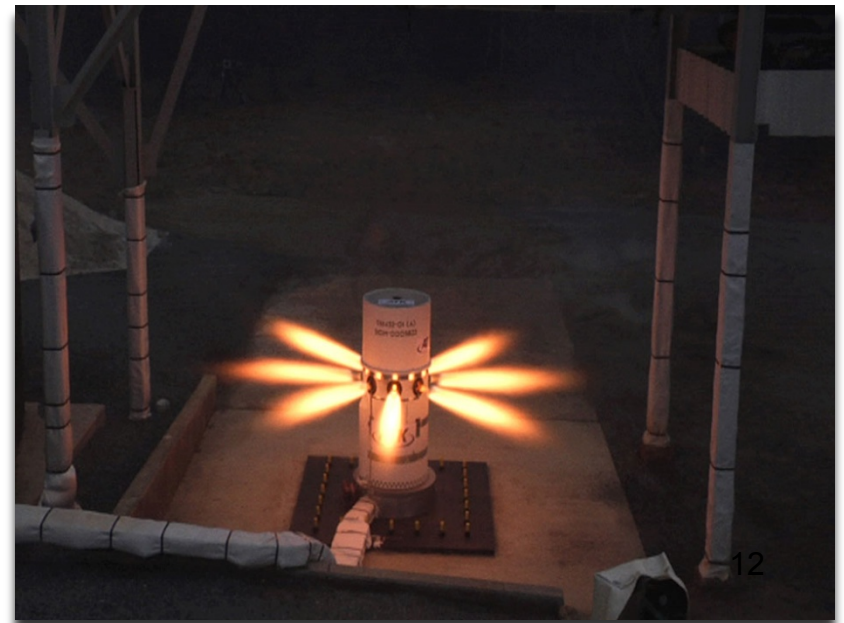
PA-1 test at White Sands was designed to fly a due North trajectory,  
At KSC, the pad abort trajectory 'dog-legs' towards the ocean



## Launch Abort Vehicle (LAV) Controller Info



- For PA-1, LAV controller was developed by Orbital-Dulles
  - PID controller, had heritage from Pegasus
  - On-board gain scheduling based on mass properties changes
  - Roll-yaw coupling (p-beta) which used a yaw command to dampen roll rates
  - Timer-based guidance
    - 0-2 seconds; open-loop pitch-over to get downrange; commanded pitch & yaw
    - 2-10 seconds; downrange guidance; commanded alpha & beta
    - 10-21 seconds; reorientation guidance; commanded alpha & beta
    - All commands turned into attitude rate commands in FSW before they were passed to the ACM controller







# Mobile Operations Facility (MOF) Overview



Telemetry, video, timing distribution, and processing equipment racks (7)

LM Command, Control, and Monitoring System racks - not shown (3.5)

Video Monitors (4)



Workstation displays (21)

Intercom panels (18)







## *Footage from various video sites*



- [PA-1 Compilation video](#)



## *Personal Experiences / Lessons Learned*



- Launch Fever, noun: An unwillingness to miss an important deadline despite known problems.
  - High speed film camera in crew module
  - SIGI-2 issues
  - ACM controller issues
  - Coyote
- Managing emotions associated with the launch
  - Went through various failure scenarios
    - Tip-over risk
    - High vibration associated with the initial pull-away
    - Risk of loss of controller authority with jet interaction
    - Risk of [parachute failure](#)
  - Stress near T-0
    - Coping techniques
- Estimating probability of mission success
  - 81 unique PA-1 related risks





## *Lessons Learned (continued)*



- Project pace & travel (4 years)
- Number of different organizations involved – always complicated
  - Flight Test Office was the responsible flight test organization
  - On some level, you needed to be Al Haig-like
- Lessons Learned take awhile to process, then recognize & identify
  - Project collected Lessons Learned just after launch
  - Lessons Learned in wind placard story



## *Lessons Learned – wind placards story*



- Surprised at how ‘basic’ things became issues that grew quickly out of control (the ‘how-did-we-get-here?’ phenomenon)\*
  - Wind placards were an example of this
    - Early on, LM Mission Analysis group identified an issue with the winds modeling in GRAM-99 with the WSMR RRA (wasn’t consistent with weather balloon data, RRA data from the 1980’s)
    - FTO agreed to go with the WSMR RRA from GRAM-2007 put into GRAM-99, our concern was that the weather balloon data hadn’t been blessed by the Air Force organization (AFCCC) that certifies RRAs
    - Using this RRA caused the LM Mission Analysis group to develop placards that were very restrictive, and it became a lot of work to get these placards expanded to reasonable operational levels
    - Control room operations were down to a minimal staff (due to MOF size), support personnel were available, but communication was sometimes spotty

\* Still working to define all the lessons learned here



# Lessons Learned (continued)



		Altitude Above WGS-84 Reference Ellipsoid (ft)														
		4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000
Azimuth Clockwise from 0° North (degrees)  Meteorological Convention (Azimuth Defines Direction Wind is Blowing From)	1-10	10.0	10.7	13.0	13.4	15.0	16.7	17.3	17.5	19.8	21.2	22.6	23.4	23.0	23.0	23.0
	11-20	10.1	11.0	12.8	13.9	15.2	15.8	16.8	19.0	20.5	22.1	24.4	24.9	25.5	25.5	25.5
	21-30	10.7	11.7	13.6	13.7	14.4	15.5	16.7	17.3	19.1	20.4	21.1	22.0	22.7	22.7	22.7
	31-40	10.3	12.5	13.9	14.5	15.1	15.7	17.1	17.6	19.0	18.5	18.5	19.7	17.6	17.6	17.6
	41-50	11.4	12.4	13.5	13.9	15.4	16.8	16.6	17.8	17.4	17.0	17.6	18.6	18.4	18.4	18.4
	51-60	11.1	13.0	13.3	14.3	14.6	16.2	16.4	15.4	16.1	16.6	17.1	17.2	17.2	17.2	17.2
	61-70	11.7	12.1	12.8	13.2	14.5	15.1	15.2	14.9	15.3	14.7	14.5	15.3	16.4	16.4	16.4
	71-80	11.4	11.7	12.8	12.9	12.8	14.6	14.8	14.0	14.2	14.7	15.7	15.7	17.0	17.0	17.0
	81-90	10.7	11.3	12.5	12.4	13.0	13.6	14.2	13.6	13.6	14.8	16.5	17.0	17.9	17.9	17.9
	91-100	10.1	11.9	11.3	11.2	12.3	13.0	12.6	13.0	13.9	14.4	13.9	14.8	15.7	15.7	15.7
	101-110	11.0	10.4	11.9	12.0	13.3	12.7	13.1	13.5	14.4	12.6	14.8	12.9	12.8	12.8	12.8
	111-120	8.8	10.2	10.2	11.0	11.5	12.1	13.3	12.0	11.1	12.1	11.4	11.5	12.2	12.2	12.2
	121-130	8.4	9.8	10.7	9.6	9.8	10.3	10.0	13.0	11.9	10.4	11.0	14.1	11.8	11.8	11.8
	131-140	8.3	8.3	8.4	9.6	10.3	12.6	8.9	9.5	10.2	9.9	13.0	10.3	9.1	9.1	9.1
	141-150	7.3	8.7	8.5	8.9	9.9	12.1	11.6	11.5	12.4	12.6	12.2	10.5	9.3	9.3	9.3
	151-160	8.2	9.6	11.0	10.9	11.0	11.2	12.2	11.7	12.5	12.4	13.3	13.6	12.2	12.2	12.2
	161-170	8.7	10.5	10.9	12.4	12.0	12.4	12.6	12.7	13.4	12.8	13.5	13.9	14.3	14.3	14.3
	171-180	9.4	11.0	12.4	12.7	13.0	14.5	14.5	14.5	14.6	14.6	15.1	15.9	16.0	16.0	16.0
	181-190	10.4	11.7	13.8	14.2	15.2	15.6	15.4	15.1	16.4	16.2	16.6	17.1	16.6	16.6	16.6
	191-200	11.8	13.7	15.8	15.3	15.7	18.6	18.3	17.6	18.8	18.2	18.7	19.8	18.5	18.5	18.5
	201-210	12.6	14.8	15.8	16.9	17.8	19.2	19.3	20.4	20.8	22.4	21.8	23.2	23.7	23.7	23.7
	211-220	13.8	15.9	17.5	18.1	19.2	21.2	21.9	22.9	24.1	25.0	25.1	26.0	25.9	25.9	25.9
	221-230	14.4	16.4	18.8	20.5	21.3	24.3	25.0	25.8	27.7	29.3	30.7	33.2	33.4	33.4	33.4
	231-240	15.4	17.6	20.1	21.2	23.1	25.3	26.4	28.7	29.6	31.5	33.4	35.9	36.1	36.1	36.1
	241-250	15.8	19.5	20.9	23.1	24.8	26.9	27.8	29.0	31.3	32.9	34.4	37.2	38.4	38.4	38.4
	251-260	16.3	18.3	21.3	22.5	24.4	26.3	27.5	30.1	32.2	34.7	36.1	37.9	39.5	39.5	39.5
	261-270	14.4	16.0	19.7	19.8	21.5	24.2	26.3	26.6	30.0	31.4	33.0	35.9	37.5	37.5	37.5
	271-280	12.1	14.2	15.6	19.0	20.7	21.9	23.9	24.7	26.3	29.4	31.8	32.1	34.6	34.6	34.6
	281-290	10.7	12.5	14.1	15.6	17.5	19.9	20.9	22.0	23.5	27.4	27.8	29.8	32.4	32.4	32.4
	291-300	9.3	10.9	11.8	13.6	15.4	17.3	18.2	20.4	22.4	23.1	23.4	24.6	26.2	26.2	26.2
	301-310	9.7	10.0	11.8	14.6	14.0	15.6	17.2	19.0	20.2	21.4	22.8	23.0	26.2	26.2	26.2
	311-320	9.7	9.2	11.8	12.4	14.2	16.2	17.4	17.4	19.1	20.1	22.2	24.3	25.5	25.5	25.5
	321-330	8.9	10.7	10.7	11.7	14.3	15.2	16.6	19.1	19.3	20.9	21.5	24.5	25.5	25.5	25.5
	331-340	8.4	9.6	11.1	13.2	13.8	15.6	17.5	17.2	19.6	22.1	24.0	24.2	27.5	27.5	27.5
	341-350	8.7	10.5	12.0	12.6	14.2	15.2	16.3	19.3	19.5	21.3	23.6	23.0	25.9	25.9	25.9
	351-360	8.5	9.6	11.7	14.0	14.8	16.1	16.4	17.4	19.8	20.4	22.0	24.7	26.6	26.6	26.6

Proposed wind placard table, not the actual table used for launch



## *Weather go/no-go call plan progression*



- Plan A: GNC & Dryden meteorologist would make the call
- Plan B: at their request, involved LM Mission Analysis personnel in weather center; GNC & Dryden MET still make the call
- Plan C: Senior Ops helps GNC in control room when complex placards are developed; GNC, Dryden MET, Sr. Ops, FTA lead make the call once we see data from weather center
- Plan D: As placard issue becomes more complex & controversial, the decision gets pushed up to the Mission Management Team (MMT is Orion PM & his support staff)
  - Used 5 weather balloons on day of launch
  - Had 924 MHz profiler next to launch site
  - Flying in the windiest part of the year for White Sands (March - May)
  - 4 day launch window (Thursday – Sunday); can't go the following week due to another higher priority program's launch
  - Day before the launch, briefing MMT on weather-101





## Lessons Learned (continued)



- After all that, balloon data showed that we were go for flight, but from the Ops recovery team and then from flight data, we learned that we were flying in 3-sigma GRAM winds that day





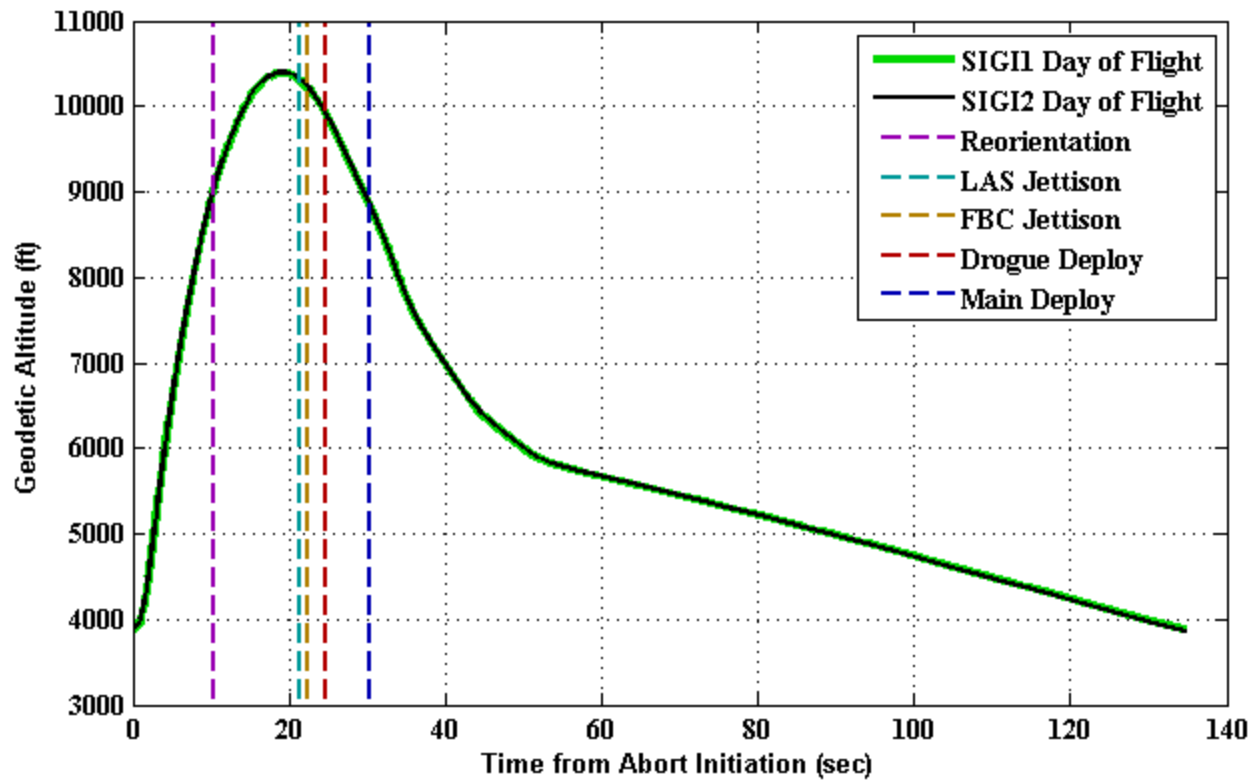
## *Lessons Learned (continued)*



- Wind Placards
  - Don't involve people in the process who don't have decision making authority; or if you do involve them, make sure they have associated with them a decision maker who has authority
  - During flight operations, a data or analysis briefing needs to come with a recommendation (ties back to authority)
    - At earlier stages of the project, analysts tend to show you all the data, so decisions can be collectively made by the team – this isn't useful or productive during operations
  - Additional LLs in work



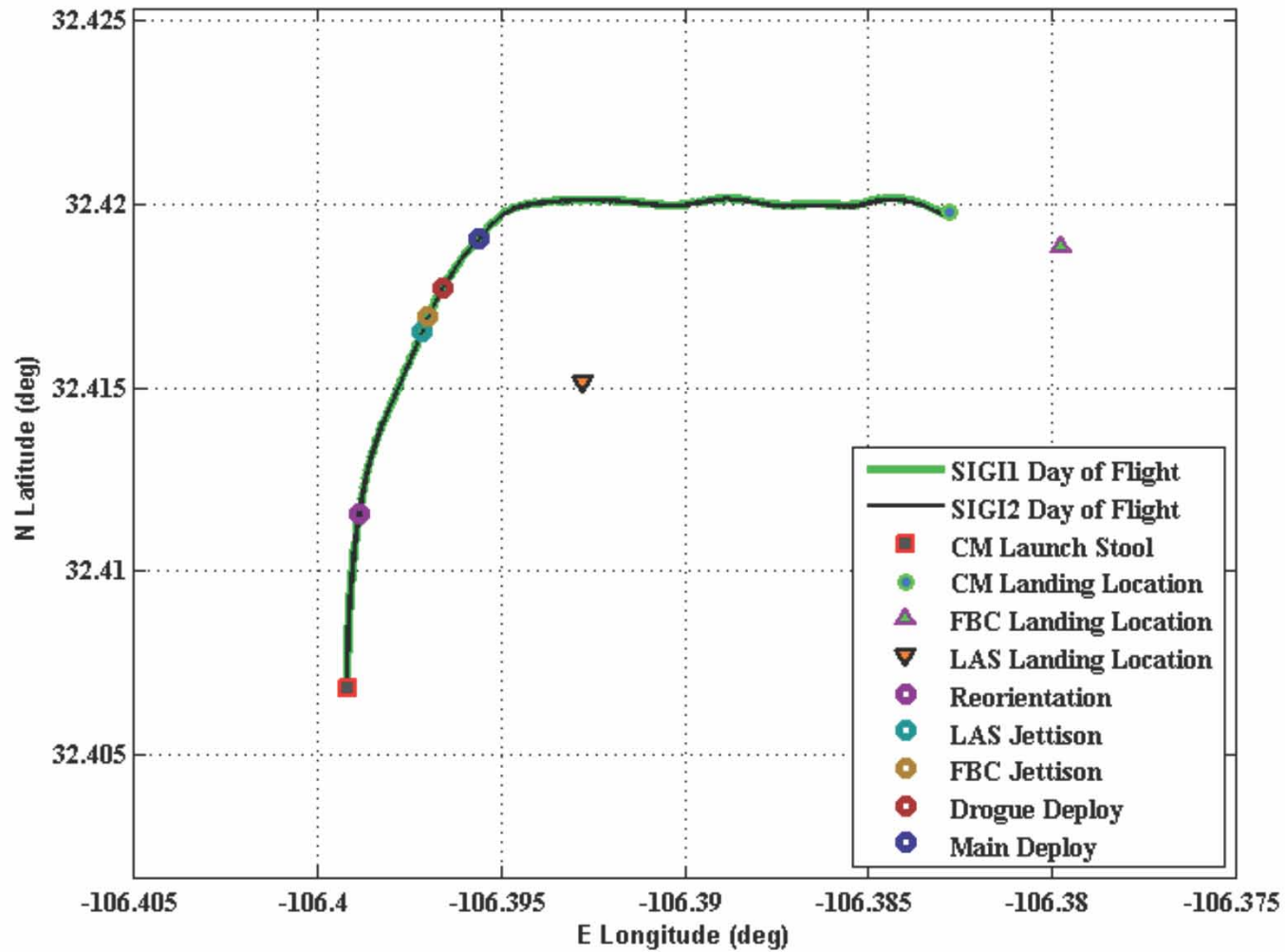
## Altitude Time History from flight



Apogee was 10,386.0 feet (geodetic)  
CM downrange was 6907.5 feet (SIGI measured)  
Total flight time was 134.4 seconds



## PA-1 Flight Test Ground Track







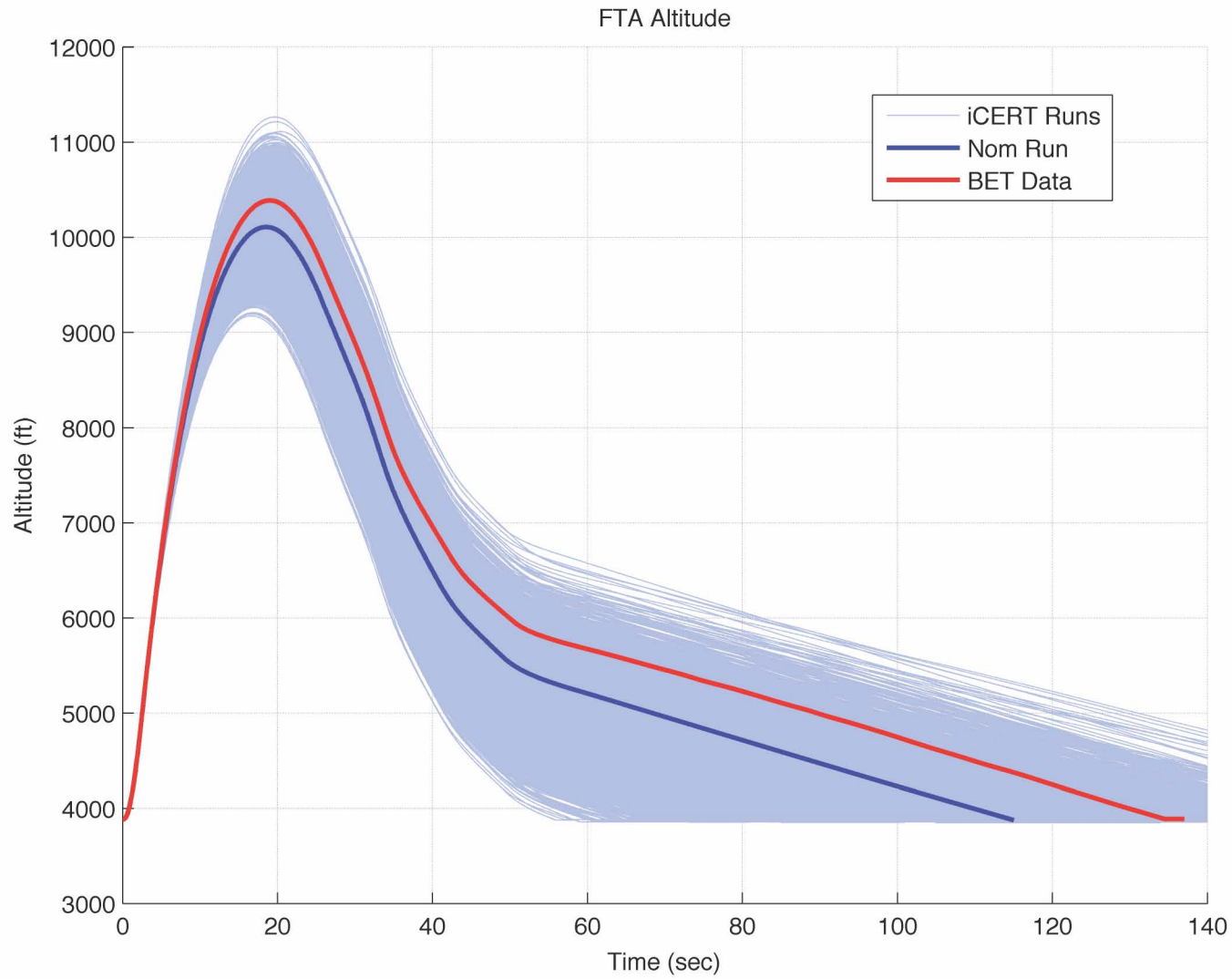
## *Post-flight data comparisons to simulation*



- ANTARES simulation runs done using post-flight updated simulation models for
  - Abort Motor thrust profile from flight
  - Attitude Control Motor thrust profile from flight
  - Meteorology day-of-flight atmospheric model
  - Mass Properties
  - Parachutes (higher fidelity models incorporated)
- Still waiting for day-of-flight aerodynamic models to come in
  - Possible that drag is not as high as pre-flight aero models predict?

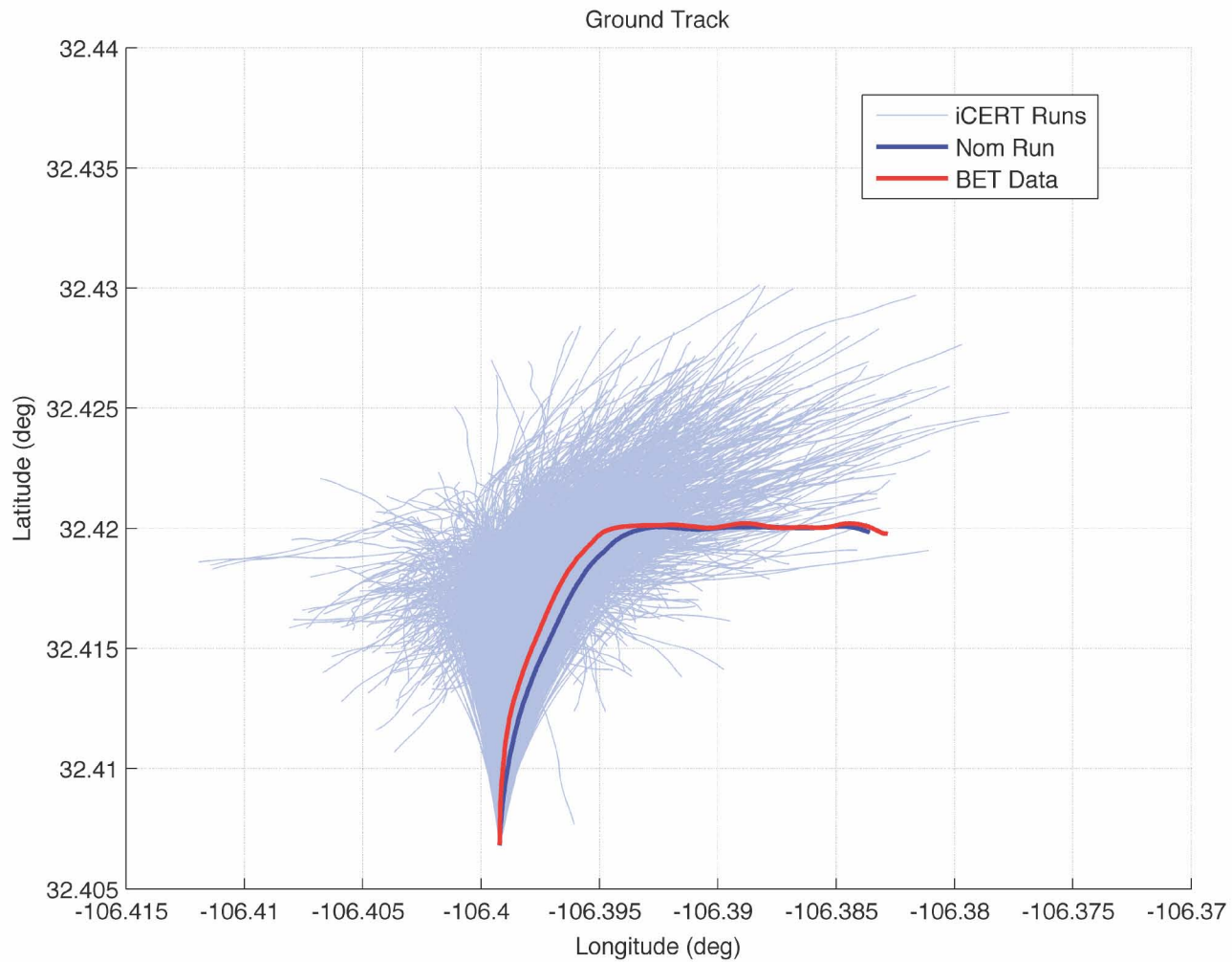


# Flight Data compared to dispersed simulation runs



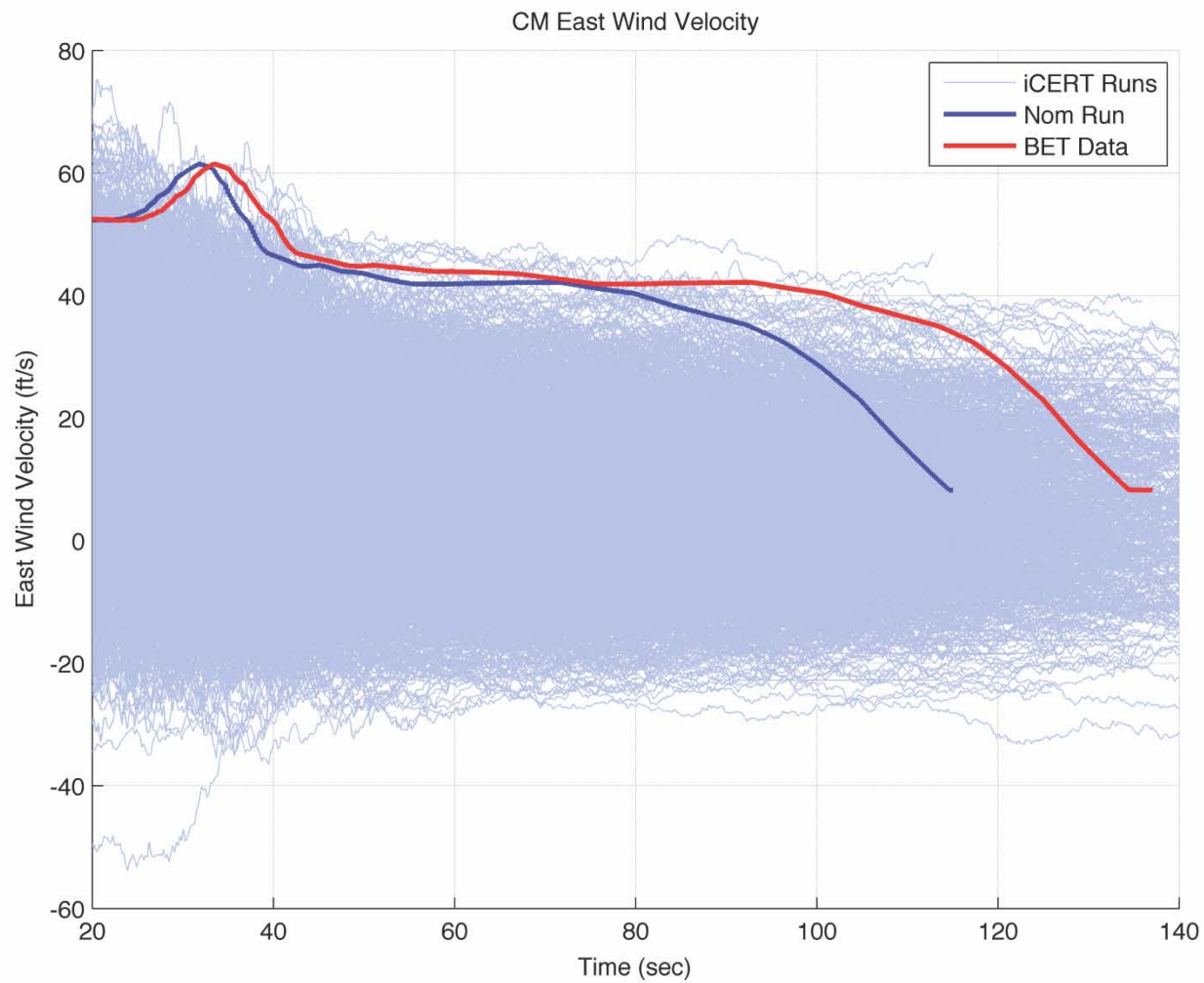


# Ground Track





# Winds blowing from West to the East





*6 May 2010 – 6:09am local time*







## *What is next for Orion & Abort Flight Test*



- Orion program management has decided to pursue OFT-1 as the next flight test
  - Test is mainly an entry test, with only a nominal LAS jettison
  - OFT-1 is a un-crewed orbital test (no docking with space station)
  - FT-2 (Orion-2) is the first crewed flight test on the manifest
- AA-2 is currently being considered as a follow on test in between OFT-1 and FT-2 (Orion-1 & Orion-2)
  - AA-2 is a transonic abort (LAS abort occurs as vehicle passes through Mach 1, about 40 seconds into the ascent)
  - Would test the production LAV controller
  - Would be performed with an abort test booster (ATB)
    - Currently SR 118 Peacekeeper motor
  - Currently performing a trade study on the AA-2 launch site location
- Production launch vehicle determination expected by Oct 31



## *Wrap-Up*



- [Ops candid commentary during flight](#)
  - Includes helicopter chase video
- Questions/Comments?